

INVESTIGATIONS OF SOME
HADRONIC REACTIONS

LARS SOLLIN



Department of Theoretical Physics
University of Lund

Lund, Sweden

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Department of Theoretical Physics
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This thesis is based on the following publications:

- I. High Energy πN Backward-Scattering models and Continuous Moment Sum Rules.
Il Nuovo Cimento 26A (1975) 1
(Together with C. Peterson)
- II. Is a "New Scaling Hypothesis in High Energy Collisions" Needed?
Physical Review Letters 34 (1975) 1199
(Together with B.E.Y. Svensson)
- III. A Soluble Realistic Model for Low Energy πK Scattering.
LU TP 77-11, to be published in Il Nuovo Cimento
(Together with N. Johannesson)
- VI. An Investigation into $K\pi$ Scattering Lengths.
LU TP 77-20

INTRODUCTION

The main task of high energy physics is to study the collisions of elementary particles at velocities comparable to the velocity of light in a vacuum, about 300.000 km/sec. The fastest particles described in paper I (the pions) have a speed which differs from this by only three parts in ten thousands and this is by no means a record in high energy physics. Such immensely violent collisions give us the best opportunities to study the innermost structure of matter. These opportunities have opened up through the rapid development of accelerators for charged particles. This development was initiated in the fifties and is still going on. The tremendous rise in the kinetic energy of accelerated particles keeps revealing new aspects of matter to us and the number of "elementary" particles produced in laboratories has risen to several hundred.

These basic constituents of matter can, of course, only be studied through their interactions, that is through the forces they exert. Four basic kinds of interaction are known, namely the gravitational, the electromagnetic, the weak and the strong interactions. I have chosen the strong interactions, better known as nuclear forces, as my field of investigation.

There is a mathematical language called field theory which is especially suited for the description of elementary particles at relativistic velocities. Field theory has been used with success in weak interactions and, above all, in the electrodynamics of the fundamental particles. It is also of great value in the study of strong interactions, where it suggests that the causality principle in nature leads to the mathematical property called analyticity for the collision amplitudes. It also predicts the related concept of crossing symmetry, which allows close comparison

of amplitudes for particle and for antiparticle reactions. These properties are heavily exploited in papers I, II and IV. However, there is as yet no basic scheme, field theoretic or other, to compute collision probabilities of hadrons, i.e. strongly interacting particles. The strong forces must therefore be studied in a phenomenological manner, in close contact with experiment.

An important point in connection with model-building is the arrival of fast computers. All papers here would have been impossible without access to a computer for evaluating integrals, minimizing functions of up to fifteen variables and similar tasks.

In the study of atomic spectra, for instance, one has a theory from which everything can be deduced, at least in principle. The lack of such a theory for strong interactions is in part compensated for by the general framework of unitarity (i.e. probability, conservation in the reactions), analyticity and crossing, and also through the considerable set of symmetry principles obeyed by the strong interactions. An impressive example is their independence of (electric) charge. As there are three kinds of pions and four kinds of kaons one might think that there are twelve different types of elastic collisions between them to be studied. Charge independence (also called isospin invariance) reduces the number of amplitudes to be studied to four! The so-called conservation of strangeness reduces them further to two.

Models in strong interactions should obey the symmetry laws and at least approximately fit into the general framework. This, however,

leaves us with a great arbitrariness in the construction of models. Still, the usefulness of specific models is great even if their theoretical foundation should be loose. They can serve to point out difficulties and peculiar phenomena which demand further experimental studies and in this way be a guide to experimentalists. One can also hope that they can approximate in a useful way the longed-for basic theory.

SUMMARY OF PAPERS

Continuous Moment Sum Rules (CMSR) are derived from analyticity properties of the scattering amplitudes. The parameters of models for high energy two-body collisions, especially the Regge pole model, can by means of such sum rules be determined from low energy data. In paper I CMSR are used to discriminate between various high energy models in πp backward scattering. The major difficulty is the lack of experimental information from the t -channel ($\pi\pi \rightarrow N\bar{N}$). It should also be remarked that the CMSR can be strictly proved to be valid only in a very limited kinematic region in backward scattering. The results single out one of the models studied as more accurate than the others.

When energies increase very much an abundance of particles are produced in the collisions. The symmetries discussed in the introduction are no longer very helpful. Much of the work in the very high energy domain consists of choosing suitable variables which describe the particle production in a symmetric and revealing way. Especially useful are so-called scaling variables which permit the dependence on some other variable to be neglected.

In a paper by Dao et al. (Phys. Rev. Lett, 33, 389 (1974)) a regularity in π^- -spectra in pp collisions was used to suggest a new scaling hypothesis tentatively called "scaling-in-the-mean". The aim of paper II is to show that the same form of the semi-inclusive pion spectra can be obtained in a simple model using only conservative assumptions, namely Feynman scaling, KNO multiplicity scaling and factorization in longitudinal and transverse momenta. Our model succeeded well in reproducing the data.

Paper III is devoted to dispersion-theoretic studies of πK scattering up to 1100 MeV. This scattering is a very convenient field for such studies because the basic principles of analyticity, crossing symmetry and unitarity can here be fully exploited. It is, however, necessary to make assumptions about the high energy behaviour of the amplitude and we have chosen to make the approximation of short range repulsion terms by Shirkov and co-workers. We also use the exoticity of the isospin 3/2 P-wave and neglect all CDD-poles. In this way we obtain a two parameter solution for the three most important partial waves. The $I = 1/2$ P-wave contains a resonance which we give the position and width of the $K^*(890)$. This fixes our solutions and together with the P-wave also the $I = 1/2$ and $I = 3/2$ S-waves come out in excellent agreement with experiment. Thus this paper demonstrates that the method Shirkov applied to $\pi\pi$ -scattering yields good results also in the πK case. In dispersion theory it is not possible to calculate the S-wave scattering lengths in πK scattering separately. One can obtain a connection between them called the universal curve. The form of this curve is

derived in paper IV using a simple dispersion relation for the S-U crossing antisymmetric amplitude. This is evaluated in the forward direction and at threshold and saturated by resonances and a Regge contribution and by approximations of the S-wave which contain the unknown phase shifts and give a relation between them. The result is in reasonable agreement with the more sophisticated calculations existing and in good agreement with the current algebra result.

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